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MODELLING OF POWER CABLES WITH LOSSES IN THE FREQUENCY DOMAIN

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ABSTRACT

An advanced model of the power three-phase cable for high frequency is created. Simulations of the power cable for low voltages in frequency domain are made. The distributions of the impedance of the power cable by 1 meter length in border mode - opening circuit and short circuit are obtained. The change of the impedance in frequency depends of mode of power cable. Resonance impedance has an importance miscellaneous for low and high frequency. The resonance frequencies of power cables with different length are determined. The models are validated in the frequency domain by investigation of transient simulations for cables with different length when they are switched into the electric energy sources.

Index Terms - Power cable, low voltage, three phase model, frequency domain, simulation.

1. INTRODUCTION

The switching of semiconductor devices is the main source of electromagnetic interference (EMI) in power converters. Fast power electronic devices generate high levels of electromagnetic emissions in the form of high-frequency currents in the conductive areas. These devices usually are the power converters and voltage transformer used for connecting renewable electricity or transformers in mobile devices. The high-frequency disturbances travel and spread over the power cables.

To study the influence of high-frequency energies on the power cable a precise models of the power cables for low voltage with different length are made, when the frequency increases.

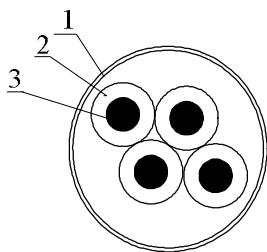


Figure 1 Structure of low voltage cable

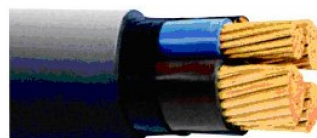


Figure 2 Low voltage power cables

2. MODEL OF POWER CABLE

An investigation type of 3 phase power cable for low voltage (LV), type CBT or CABT [4] consists of three conducting cores and neutral core, which are insulated and covered with PVC sheeting (figure 1).

In figure 1 are designated: 1 - cover of cable, 2- insulation; 3 – copper or aluminum conductor.

Type of the low voltage cable CBT is shown on figure 2.

A cable model for high frequencies by distributed parameters is created. The simple cell circuit with distributed parameters - "L" type for presentation of the power cable per one meter and in single phase is used [1]. It is presented in figure 3.

Models of single phase power cable and power cables with 2 conductors for low voltage are made in [1]. There the created models are investigated for high frequency in frequency domain.

The values of the parameters of the cable length per 1 meter are determined, based on measured values of the active resistance R and inductance L on conductor, capacity C and conductivity G of the main isolation. Metric bridge HP4294 was used.

A model of the three-phase cable of low voltage for high frequency is shown on figure 4.

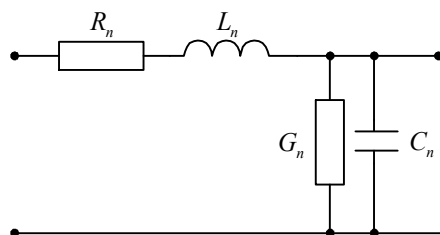


Figure 3 Model of cable simple cell of high frequency

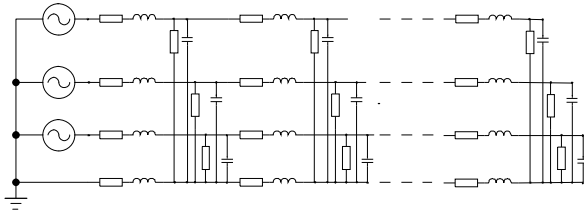


Figure 4 High frequency model of three phases LV cable

To simulate a length of cable with 1 meter, the models with 8 numbers of elementary cells is used. The values of parameters are: the active resistance R is $4 \times 10^{-3} \Omega/m$; the inductance L on conductor is $17.4 \times 10^{-9} H/m$, the capacity C is $1.8 \times 10^{-12} F/m$ and conductivity G of the main isolation is $0.26 \times 10^{-7} S/m$.

Cable with 1 meter length, presented as a circuit with distributed parameters by 8 elementary cells, is investigated thoroughly.

3. SIMULATIONS IN FREQUENCY DOMAIN

The resonance frequency of cable is determined.

In the first stage the model of 1 meter length is investigated. It consists of 8 cells.

In the input of the three phase LV power cable sinusoidal generators is connected. The amplitudes of generators are 1 V.

The simulation in frequency domain of low voltage cable, presented by 8 elementary cells, in mode of open circuit, is shown in figure 5.

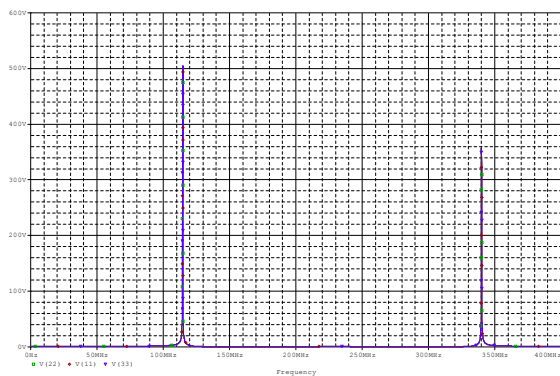


Figure 5 Simulation of 8 cells model of three phase cable

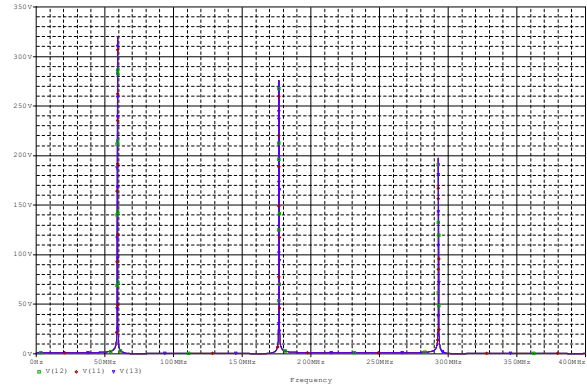


Figure 6 Simulation of 16 cells model of three phase cable

In mode of opening circuit main resonance frequency of cable, presented by 8 cells (1 meter length) is 114 MHz and next resonance frequency is 346 MHz, respectively.

In the next stage a length of cable more than 1 meter are investigated. The models with different number of elementary cells - 16 and 32 are introduced.

The simulations in frequency domain of low voltage cable, presented by 16 and 32 elementary cells, are shown in figure 6 and figure 7.

In mode of opening circuit resonance frequencies of cable, presented by 16 elementary cells (length of 2 meters) are 59 MHz, 176 MHz and 292 MHz, respectively.

In mode of opening circuit resonance frequencies of cable presented by 32 elementary cells (length of 3 meters) are 30 MHz, 140 MHz and etc., respectively.

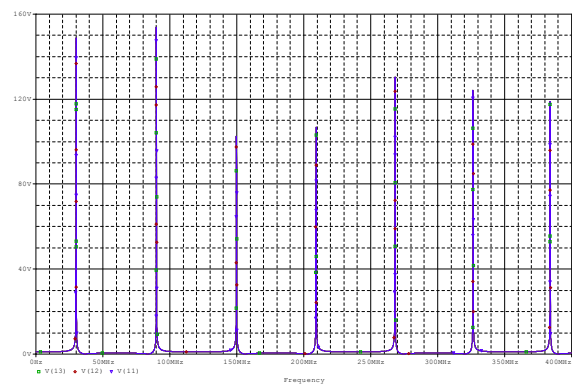


Figure 7 Simulation of 32 cells model of three phase cable

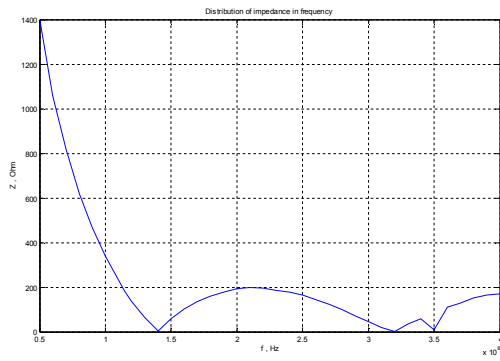


Figure 8 Distribution of the cable impedance in the frequency by open circuit

An interest presents modeling of power cables in border events - open and short circuit.

The distribution in frequency domain of the impedance of the cable with a length of 1 m in both border cases - opening and short circuit is obtained.

The distribution in frequency domain of the impedance of the cable, presented by 8 elementary cells in figure 8 and figure 9 are shown, respectively.

The models are simulated and validated in the frequency domain by investigation of transient cases.

In this case the cables are switched into the electric sources with high-frequency energies from power converters and etc.

In the input of the three phase LV power cable sinusoidal generators with single frequency is connected.

The parameters of generators are: amplitude 10 V and phase shifts 0, $-2\pi/3$ and $2\pi/3$ rad, respectively.

A mode of opening circuit is considered.

The simulations of transient analysis of low voltage cable, presented by 8 elementary cells (1 meter of length) are shown in figure 10.

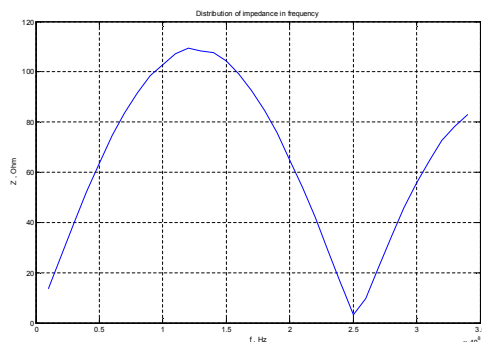


Figure 9 Distribution of the cable impedance in the frequency by short circuit

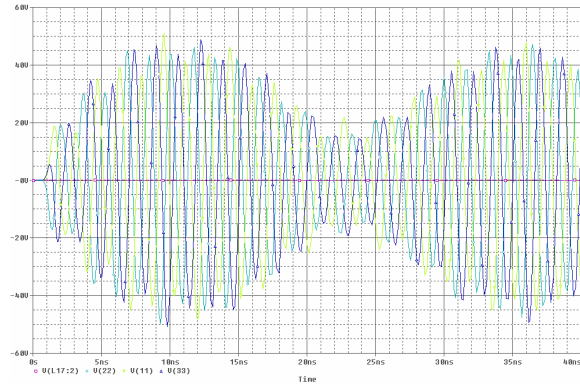


Figure10 Transient simulation off three phase cable model with 8 cells

In this case by the connection of three phase generator in power cable with 1 meter length the maximum voltage is approximately 50 V.

In the next stage the cables with large length are considered.

The simulations of transient analysis of low voltage cable with length of 2 and 3 meters, presented by 16 and 32 elementary cells, are shown in figure 11 and figure 12, respectively.

By the connection of three phase generator in power cable with 2 meter of length the maximum voltage is approximately 30 V.

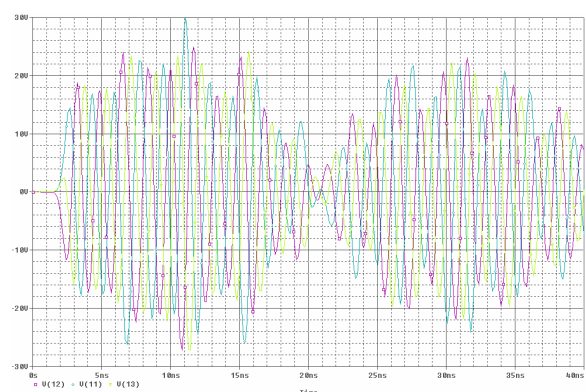


Figure11 Transient simulation off three phase cable model with 16 cells

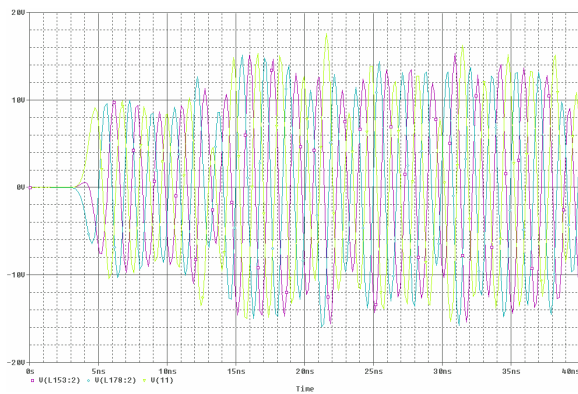


Figure12 Transient simulation off three phase cable model with 32 cells

By the connection of three phase generator in power cable with 3 meter of length the maximum voltage is 18 V.

The transient regime is faster for cables with greater length.

However in some cases, an unstable state of the circuit can be obtained.

4. CONCLUSION

An advanced model of the power three-phase cable for high frequency is created.

Simulations of the power cables for low voltage in frequency domain are made. The distributions of the impedance of the power cable by 1 meter of length in border mode - opening circuit and short circuit are obtained. The change the impedance in frequency depends of mode of power cable. Resonance impedance has a miscellaneous importance for low and high frequency.

The resonance frequencies of power cables with large length are determined.

The models are validated in the frequency domain in the case of connecting of power cable with high-frequency energies sources.

The investigations of frequency and transient simulations for cables with different length are described.

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